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EXPERIMENTAL APPLICATIONS OF PREDICTIVE MODELING IN ARCHEOLOGY

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Abstract

As Boast put it righteously "there is no basic difference in the way of human thinking between primitive and civilized cultures" starting off from the first intentional deeds, through the man of the medieval times up to the modern man of today. Settlements are generally established in areas where the environment is capable to support human needs. Thus the environment is an important influencing factor on the presence and distribution of humans, and this special relationship must be also quantifiable, analyzable in a given way.

The major aim of the present study was to shed light onto various phenomena and their interrelations, the collective appearance or presence of which may refer to the existence of a prehistoric, mainly archean archeological site nearby with great certainty in an area with measurable physical properties or parameters. With the help of the exposed relationships a category map can be prepared for a less investigated area, which depicts the probability for the presence of a human settlement or archeological site. The gained results may be a good starting point for planning future excavations or any other kind of research.

Thanks to the large-scale variety of data and procedures applied in the model, the collective usage of different analytical and statistical methods and approaches had to be utilized in our work ranging from the fields of geostatistics (logarithmic regression analysis) through geoinformatics (digital elevation model) to remote sensing (Landsat TM indexes).

Keywords: predictive modeling, GIS, geography, archeology

Introduction

There has been a really spectacular increase in the demand of getting to know our past and cultural heritage especially for the last few years. On the other hand, the available financial resources for widening our information background on the subject have experienced a relative drop.

This is truly alarming, as the detailed survey and analysis of even a small area may require huge sums of money. Another major problem comes from the fact that only a small portion of the known, plus the not yet discovered but existing archeological sites have been documented by archeologists so far, yielding some sort of data loss complemented by a continuous perishment of artifacts causing a similar problem.

All these alarming phenomena called for the development of special methods and approaches, which may on the one hand reduce the amount of money necessary for detailed field surveys via increasing the number of known sites on the other hand.

One such efficient approaches might be the construction of predictive models.

The practice of predictive modeling is quite common from the middle part of the 1980s, initially used only in medicine and business planning. However, it has recently becoming more and more widespread in archeological research as well. These models allow for the spatial and temporal expansion of known patterns and interrelationships. Thus they might be extremely useful in archeology as well.

Archeological predictive modeling is based on the assumption that human settlements generally develop in areas offering ideal natural endowments to meet the demands of human cultural groups on the one hand. On the other hand, it also presumes that traces of the former environmental conditions can be relatively well assessed even today as well, even if it requires the application of indirect methods mostly. The major purpose of the constructed model was to reveal these traces and those differences between them, which might have had a decisive role regarding the development of a human settlement or archeological site. In other words, the major task of archeological predictive modeling is to offer a reliable identification method of those natural and social factors, which had fundamental influences on human activities and regard the settlement as a feedback given to these factors by human communities.

The clear distinction between settlements and other areas is fundamental, giving the basis of the algorithms used in the model for the statistical classification of the studied parts of a pilot area via the measurable parameters of the surrounding environment and noting the possibility for the presence or lack of settlement sites in the pilot area. Consequently, these models are capable to predict the probability of the presence of such settlement sites in a given pilot area via the quantitative analysis of the environmental parameters. One of the major strength of the method is the utilization of explicit data and variables enabling the adequate reproduction and verification of the received results.

One of the practical benefits of the model is its applicability to extensive, less investigated areas, where the majority of archeological sites or former human settlement sites are not yet. Knowing the predicted distribution probabilities is useful for several reasons. With the help of the results of the model, one can get a clear view of not only the probabilities for the presence of archeological sites in a pilot area, but can receive useful information on the parameters, which might have actually influenced the development of the settlement itself as well. Furthermore, these models might be useful in planning regional management and development measures via highlighting the areas worthy for protection. As from 2001 during the course of a general land resource assessment (filing a conception of urban development, local construction regulations) the preparation of a detailed survey regarding the presence and distribution of cultural heritage values is compulsory in Hungary. Models with such scope may be extremely useful in these applications as well, since as one chapter of the bill says "all areas where the potential presence of archeological sites can be justified or presumed should be considered as archeological areas worthy of protection, including all natural and artificial ditches and watercourses as well". This is exactly what we are doing with the help of our predictive models. Furthermore, the gained results may be also useful in other research applications as well.

The present study is a clear example of the first experimental application of the above mentioned modeling method to local Hungarian examples. The results are mainly applicable to prehistoric sites.

Material and methods

The pilot area

The area chosen for detailed analysis is located in Békés county, at the interface of the southern marginal areas of the basin of the Hármas-Körös and the Békés-Csongrád Lowland, covering an area of about 130 km2 north of the city of Békéscsaba. (**Fig. 1.**) The most important geomorphological forms are two Pleistocene abandoned riverbeds of the ancient river Maros, presently signified as Hajdú-(Kamut) valley, and Kondoros brook, located east of the former. These channels were active riverbeds even during the Oldest Pleistocene as well (from 2.5 MA to 650 ka) corresponding to the northernmost margin of river migration as well.

The channels were not active during the Holocene, receiving water supply only from the rainfall and groundwaters forming a continuous water surface in these inactive riverbeds. It must be noted that during times of high floods, when floodwaters also managed to reach these channels, they might have been turned into active watercourses, acting as drainage channels on the floodplain.

The geomorphology of the Pleistocene was fundamentally determined by the alluvial fan deposits of the river Maros, composed of coarse sands and gravels. This setting fundamentally determines the general morphology and view of the referred landscape even today as well.

The former loess steppes, constituting the original natural vegetation have been replaced by extensive arable lands. Traces of the original vegetation are observable in some protected areas only, like the Cumanian burial mounds. And their former extents are known only from written historical sources.

Data utilized

The following types of data groups have been used in our work:

- Topographic data
- Spectral data
- Soil data
- Attributes

As a first step a digital elevation model depicting the relief conditions of the area was prepared. For this stereographic maps with a scale of 1:10000, frequently used by archeologists were scanned and transformed into the national uniform projection system (EOV). Afterwards, contour lines and elevation points were digitized and the received layers were used for the construction of the DEM using the software pack Arc/Info 8.1.

The archeological sites identified by archeologists during the course of field surveys were depicted on the scanned maps, so they just had to be transformed into a digital vector or raster format from the corrected digital maps.

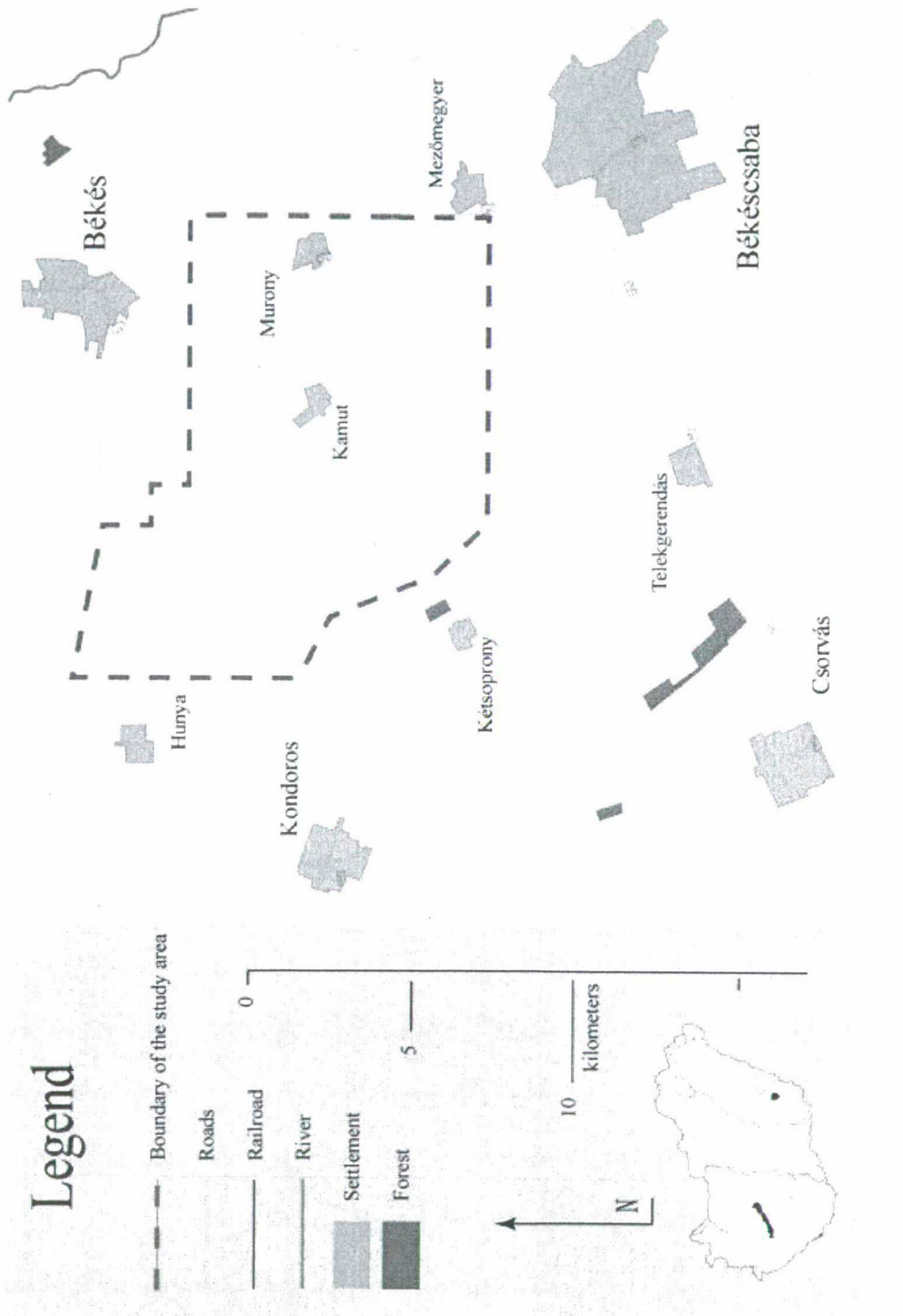

Figure 1. The location of the pilot area

The utilized spectral data, deriving from Landsat and TM satellite images correspond to such environmental parameters as soil temperature and humidity, as well as vegetation cover. These were received via the use of the ERDAS IMAGINE 8.4 software pack.

The low resolution (30 m) of the photos hampered the possibility of getting direct information on the location of the individual field objects. However, with the calculated indexes the individual areas could have been ordered regarding the probabilities for the presence of these objects.

The soil map layer was already in a digital format with a scale of 1:25000. The descriptive attributes of the model storing the name, age and code of the archeological sites derive from the archeological field reports and the volume entitled the Archeological Topography of Hungary.

Data processing was carried out in two steps. As a first step the raw data were transformed into a digital format, unless it was in that format, creating layers readable by the GIS software systems serving as starting layers for further analysis of the utilized environmental variables. These are the so-called primary layers.

The second step involved the construction of the so-called secondary layers, which contained only those variables deriving from the analysis of the primary layers, which directly participate in the modeling process.

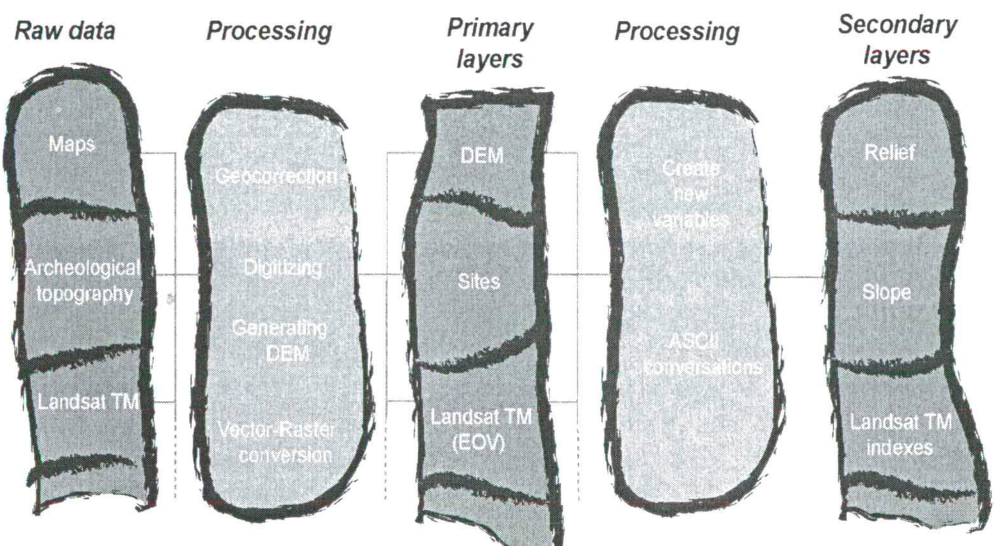

Figure 2.a The steps of predictive modeling (after Warren)

Raw data: maps, archeological topography, Landsat, TM photos; Primary Processing: transformation, digitizing, DEM construction, vector-raster conversion Primary layers: DEM, archeological sites, Landsat, TM (EOV) Secondary processing: new variables, ASCII conversion Secondary layers: relief, slope, Landsat, TM indexes

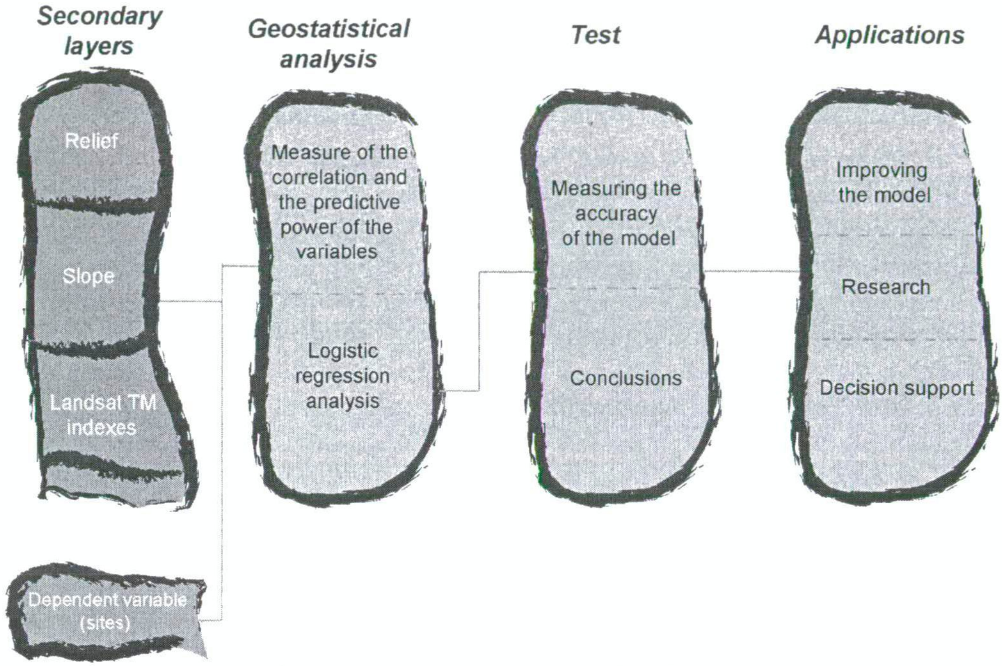

Figure 2.b The steps of predictive modeling (after Warren)

Secondary layers: relief, slope, Landsat, TM indexes, dependent variables (archeological sites) Geostatistical analysis: correlation and applicability, logistic regression analysis Testing: verification of predicted results, conclusions Usage: model improvements, research, support for decision making

Methods

The application of predictive modeling requires three major steps:

- Choosing dependent variables
- Choosing independent variables
- Assessing the relationship between these two variables

First let us have a look at what we can consider as dependent and independent variables.

Dependent variables were the raster layers containing information on the archeological sites, where the cells covering the sites were assigned a value of 1, while those cells not covering the sites received a value of 0. Cells located outside the pilot area had a value of NODATA.

The independent variables – in the factor of which we are examining the probabilities of the presence of sites- are the environmental parameters such as slope, exposure, relief, soil humidity, vegetation cover, genetic soil types, excess surface water inundation, and distance from watercourses.

Most likely, a lot of critics will let me know after the reading of this paper that there is not a single social or cultural component among these variables. And you know what they are absolutely right, at least, partly.

Since the cultural evolution of a human group is a very complex process, there is every reason to believe that nature and the parameters of the environment are important not only in the initial phase but during the whole process greatly influencing the shaping of thoughts and deeds. To put it in another way, in my opinion the characteristics of a culture as well as its demands are fundamentally determined by components of the environment giving the background of its birth as long as the culture is not modified by other external effects.

This must be applicable to hunting-fishing-gathering groups of humans as well as those dwelling on the steppes where the most common ornaments are all organic or naturalistic, referring to the former site and mode of the origin of that culture.

Of course, the non-natural parameters are also important. I just wanted to notify that their complete lack does not necessarily result in the total unreliability of our final results.

After the creation of the sufficient number of dependant and independent variables, their interrelationship should be assessed somehow in the next step of the analysis.

For this let us turn to the method of logistic regression analysis.

Logistic regression analysis

Several statistical methods have been utilized in the process of predictive modeling so far. However, the most popular and common of these is that of logistic regression analysis (ALLEN et al., 1990). This type of regression analysis developed from the method of linear regression. Regression analysis is the best tool for predicting the dependent variable values knowing those of the independent variables, in other words to reveal the relationship existing between two or more variables. In our case we were to shed light on the relationship between the archeological sites and the environmental parameters or components. In case of the logistic regression analysis the dependent variable is dichotomic – has dual value –, the best prediction is related to the probability of actual occurrence or happening, expressed as the logarithm of the quotient of the probability of occurrence and that of none occurrence (CSABA et al., 1997).

During this step our independent variables were introduced into an equation, which predicts the probability for the occurrence or non occurrence of an event in the studied area.

The equation of the process for several independent variables is:

$$p(B) = \frac{-1}{1 + Exp(\alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i)}$$

where p(B) is the probability of occurrence; Exp is the exponential function, α is the section constant, representing the value of the dependent variable, when $x = 0$; βi is the component of independent variables; xi is the independent variable for the suitable βi coefficient. The procedure uses the so-called maximum-likelihood method for calculating the values of α and β.

This analysis was implemented in the software environment of Arc/Info 8.1 yielding a raster map, where the value of the cells represented the probabilities for the presence of archeological site in that cell unit with values between 0 and 1.

For verification purposes before the second run about 40% of the archeological sites was left out of the analysis using a random function. Thus by applying these removed sites onto the received maps the accuracy of the predictions could have been easily observed.

Results

In the final maps depicting the prehistoric archeological sites the points with the highest probability values were almost all restricted to the areas of the ancient riverbeds (**Figure 3.**). These points managed to perfectly delineate the Kondoros creek. The area of the Hajdú valley was less precisely contoured, but could have been clearly identified.

This must be attributed to the fact, that the area of the Kondoros creek is in a relatively lower position compared to that of the Hajdú valley thus must have enjoyed more waters as well.

The actual sites relatively well correspond to the predicted values. Furthermore, with the help of these values the location of the sites, left out of the analysis for verification purposes, could also have been relatively "precisely" identified.

The scattered peak probabilities along the Kondoros creek must correspond to the former embayments as well as the deepest parts of the ancient channels. As the area was generally poor in surficial watercourses during the Holocene, open water areas must have been restricted to the deepest parts of the former channels only. So it's quite apparent why many sites turned up in these areas.

Calculated probability values, contour line of the sites

The calculated probability values mostly draw out the outline of the former channels and the once existing morphological features of the area (the correlation coefficient between the probability values and the relief values is 0.8).

Consequently, the natural endowments must have played a crucial role in the settlement strategy and location of the ancient prehistoric human communities.

The model was run for three other cases too, when sites of three distinct historical periods present in large numbers in the pilot area were individually depicted (the age of the Sarmatians, Avars and the Arpadian period).

However, only the presence of sites connected to the channels could have been clearly justified with this method. It must be attributed to the fact, that these cultures were not as much dependent on the natural endowments of the area as the formerly examined prehistoric archaic groups.

To improve the reliability of predictions, in these cases the social parameters must also be given consideration in the models.

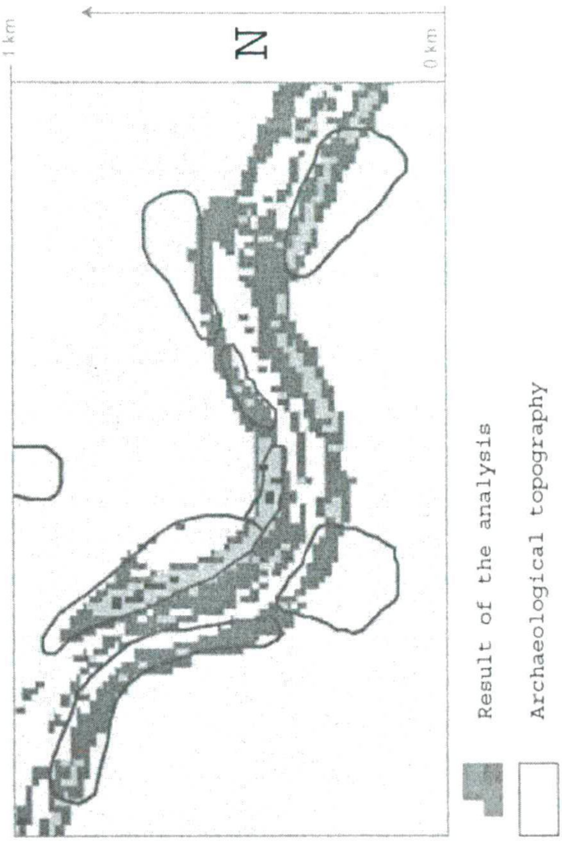

Figure 3. The final map with the location of the archeological sites depicted

Summary

On the whole the newly established predictive model was suitable for predicting the probability of the occurrence of archeological sites dated to the archaic prehistoric period. Thus the primary goal in the initial identification of these sites preceding archeological field surveys and understand the spatial characteristics of the identified settlement types was met for the period of the archaic cultures. However, in case of the younger cultural groups the results were not convincing and the model requires improvements.

There must be several reasons for this. It's possible that the quality of the raw data used for the calculation of the independent variables was not fully suitable for the task; like for example they derive from a Landsat image taken during a drought. Another possible source of error might result from the improper assignment of the sites during the field surveys, as in the practice of archeological topography even five pottery remains or fragments are considered to represent a site as well. Thus the exact delineation of such sites is utmost impossible via the application of the predictive method. Moreover, data on such sites are even harmful regarding the success of the outcome.

Despite all this, the utilized independent variables seemed to have yielded acceptable results in predicting the presence of archaic archeological sites. Since the actual physical parameters of the environment had the most decisive role in the settlement strategy during this time period.

In order to attain higher accuracy, the selection of the layers containing information on the natural environment should be carefully revised and tested. Furthermore, the introduction of the social and cultural parameters into the model may also enhance the reliability of the application rendering it suitable for use in the case of younger cultures as well in the future.

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WATER SUPPLY AND VEGETATION SYSTEM OF STREAM CIBULKA

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Introduction

The Stream Cibulka located in front of the Velencei Mountains (**Fig. 1.**) was probably not a „significant" water course either at the time of its first military depiction (in the second part of the 1700s). The spontaneous nature of the vegetation of the small water course surrounded by fields already at that time, distinguishes the stream from the surrounding areas. Thus, although the water course does not have any special natural qualities, it poses several interesting questions which can be considered to be "up-to-date".

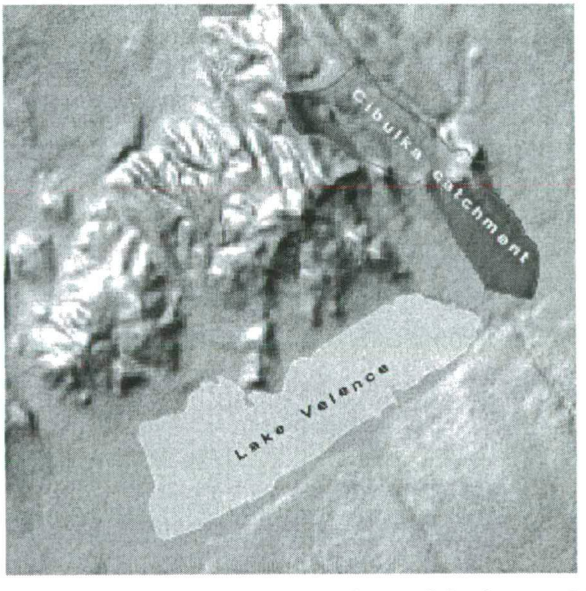


Figure 1. River basin and the surroundings of the Stream Cibulka

The Stream Cibulka is a temporary water course. Its river bed is basically man-made in its overall length, it has a straight run-off and a regular cross-section (obtrapeziform) (**Fig. 2.**). The wetland, which undoubtedly used to surround the stream, has now almost completely disappeared. The same thing happened to the "services" provided by this wetland free of price. Recognizing this problem, there have been more and more efforts aiming at revitalisation-rehabilitation activities (NAGY, 2001; UDVARDI, 2001).

Approaching the subject from this perspective, we ask questions regarding particularly the environmental science, since our aim is to influence our own habitat and to establish more favourable conditions for ourselves.

Ecology has a different approach towards the same subject. Its main area of interest is the question, which species does this small regulated water course (water channel at the site, we would perhaps prefer using the expression water cannel instead), which has been surrounded by fields for centuries and which has a river basin that has been intensively cultivated until today, serve as a habitat. Furthermore, to what extent is the vegetation system in accord with the soil qualities, among them the parameter of water supply.

A potential question from the point of view of Geography (which induces a similar analysis) is the following: where and what sort of wetland does the relief of the river basin and its soil qualities predestinate?

Figure 2. Man-made bed fragments of the Stream Cibulka (taken in April).
Photo by Károly Barta

We have planned our analysis on the basis of the following approach:

1. Relying on the coenological samples and the relative ecological figures (relative groundwater and humidity index (WB)) we examine this kind of differentiation emerging in this vegetation.
2. We record some environment parameters that determine water supply.
3. We compare the results obtained.

To put it briefly, - out of the several questions arising in connection with the topic – we aim at answering the following: What kind of relation is there between some environmental parameters determining water supply and the differentiation in the vegetation?

The Stream Cibula was last regulated in 1982-83, when its overall length was regulated uniformly. The documentation called "Plan on the Recultivation of the Stream Cibulka" [„Cibulka-víz jókarbahelyezési terve"] gives an adequate picture of the work and the current state.

This documentation also contains the only evidence questioning the spontaneous character of the vegetation. It mentions a possible planting of *Baldingera arundinacea* on the lower section of the stream in order to secure the riverside of the newly made bed.

The relative ecological value figures (BORHIDI, 1993) include the likelihood rate of occurrence of the different plant species summed up in relation to the given parameters on the basis of the landscape approach. When we depart from the "prize-chosen" approach, it might result in the wrong interpretation. This also applies to the vegetation criteria that are in accordance with the habitat factors. In connection with the application of these indexes, conditions have a particularly important role (BARTHA, 2002).

Material and methods

We determined a 4.4 km long section of the Stream Cibulka from its spring to the highway M7 to be the examination site. The remaining section of the stream to the water course Vereb-Pázmándi (the estuary is on the territory of Kápolnásnyék) is 2 km long and flows mainly through an inhabited area (there are some places where the river bed is concrete-covered and enclosed), that is why this area we left out of the examination. On the stream segment examined sheep is grazed at irregular intervals; at some places the bed is deepened so that the sheep can drink.

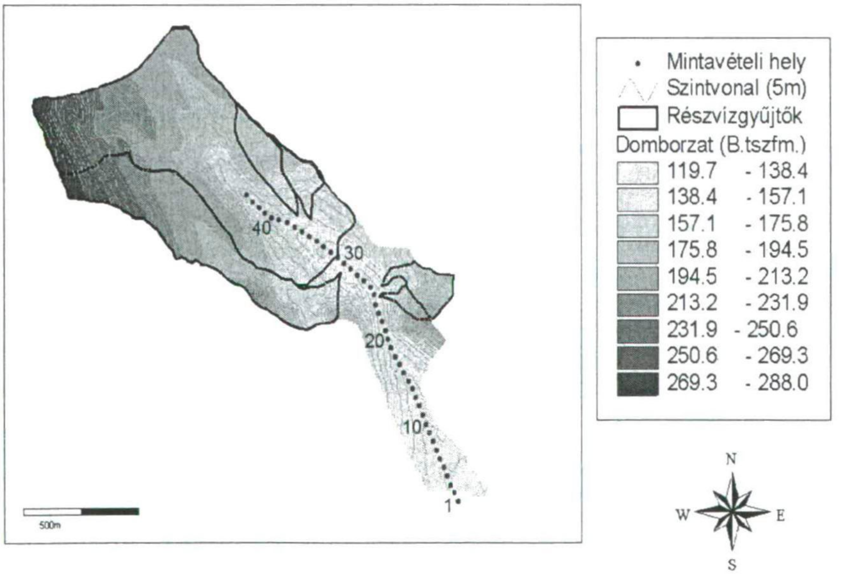


Figure 3. Sampling sites on the river basin and the bed-bottom belonging to the stream section examined

The sampling sites were determined at every 100 meter along the stream. The starting point was determined at random. The numbering of the 44 sampling sites (point 1) starts with the endpoint of the examined section opposite the spring. Thus the spring (the highest point of the man-made bed) is the sampling point 44 (**Fig. 3.**). The vegetation at the bottom of the obtrapeziform bed was characterized by taking coenological samples.

The middle point of the 0.6×1.5 metre sized squares followed each other in every 100 metre. The length side was parallel with the bank sole, the width side was adjusted to the squares located on the narrowest bed segment.

According to the data of the technical plans the width was 0.6 metre (ranging between 0.6 and 1.5 metres). The length of the squares of 5 metres resulted from the consideration of two factors.

Supposing a continuous change or transition in connection with the water supply along the stream, it was appropriate to determine the length of the square to be as short as possible. The other factor considered was to calculate the minimal dimension on the basis of the experience based on the classic coenological data. The coenological samples were collected in the last week of May 2004. We estimated a proportional coverage species by species and an overall coverage. The names of the species and the relative ecological figures (WB) correspond to the ones in the work by Borhidi (BORHIDI, 1993).

At every sampling point a hole was bored into the lower third of the bank slope with a hand drill until reaching the groundwater, then it was plugged with a long-shaped plastic bowl. From April (when the wells were deepened) until August the depth of the groundwater-plane was read at the beginning of each month (between the 6th and 10th). At places where we could not reach the bed bottom after boring 1.5 metres below the groundwater-plane, we stopped boring.

Measuring the height between the bed bottom and the well ledge the distance between the groundwater-plane and the bed bottom could be calculated from the data on the groundwater depth. When the groundwater-plane was measured monthly, it was also recorded whether the bed bottom was dry (bed has dried up) or wet (there was water in the bed).

The data obtained this way make it possible to make a distinction between the influent and effluent segments at every sampling time, so it can be stated that if the groundwater of the areas located on both sides of the bed supply (effluent) or rather drain (iffluent) the water out of the bed.

The soil samples were collected in June 2004. An undisturbed soil sample (0-5 cm) and a surface soil sample weighing approx. 1 kg (0-10 cm) were taken from the middle of the squares of the coenological samples at each sampling point. Following a general sample preparation, the Arany-type soil cohesion index and the vegetable matter content was determined (Tyurin method (BUZÁS, 1988)).

The digital relief model of the river basin and the borders of sub-basins were identified with the program EROSION 3D.

Results

Assessing the data of the groundwater wells

We have summarized the results in **Fig. 4.** The 0 point on the value axis and the horizontal line cutting this point stand for the bed bottom. The positive values (above the horizontal line) indicate that at those points it was the groundwater (spring) that supplied the stream with water.

In these cases some water can be found in the bed (which may also partially result from surface onflow). As for the negative values, the groundwater-plane did not come to the surface in the bed sections belonging to the given sampling point. In the present case the bed can both be dry and wet (should there be some surface onflows).

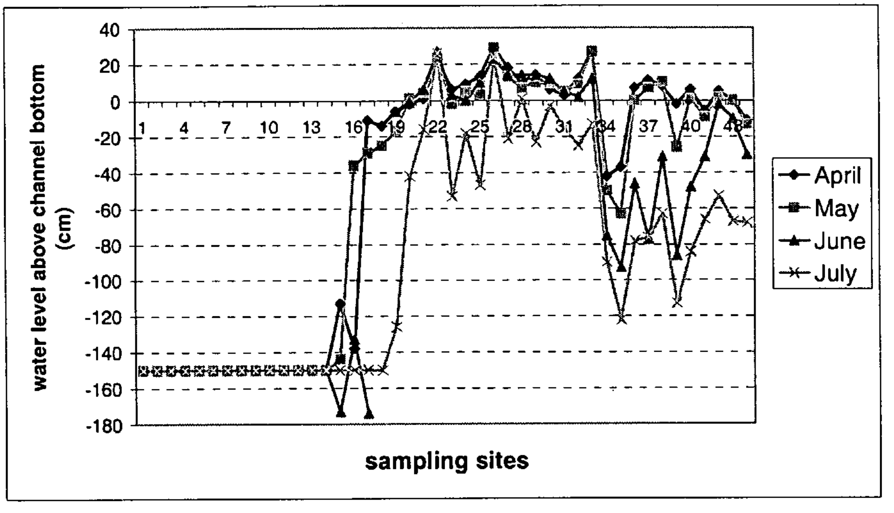


Figure 4. Location of the groundwater compared to the bed bottom

The first 14 sampling sites are uniform regarding the fact that the groundwater was found deeper than 1.5 metres at the time of all the four sample collections. Supposing that the groundwater-plane located deeper than 1.5 metres cannot be the water spring for herbs living in the bed, its depth was not relevant for the examination. The points on this segment of the stream are differentiated on the basis of the data obtained from the groundwater wells. At the remaining 30 points of the examined section in 94% of the cases the groundwater was found in a depth of max. 1.5 metres. In the following this segment is the focus of our examination. In general, it can be stated that the groundwater at all sampling sites decreased at the sampling collection times. The inaccuracy of the measurement was within 5 cm. The water level risings occurring occasionally were within the inaccuracy limits, thus it cannot be claimed whether the water level rising was real. From the point of view of the data obtained at four times and that of the aim of the examination, it is not significant. The pace of the decreasing varies at different sections of the stream. On the basis of this, the 1.2 km long segment located between the points 20 and 32 differs significantly.

A common feature of these points is that on the basis of the data obtained from the first three measurements (April, May, June) the groundwater did not exceed the decrease of 10 centimetres. Considering the data from July this segment is no longer uniform, as at some points the extent of the decrease of the groundwater exceeded even 40-50 centimetres (sampling sites 20, 23, 25); at other points the alteration was within the inaccuracy limits. Comparing the data indicating whether the bed is wet or dry (**Fig. 5.**) and the diagram it we can state that the stream had only four springs at the beginning of July.

There are six sampling sites where the bed contains water, however, there are only four of them where the groundwater comes to the surface (points 22, 26, 28, 30). At the point 30 the groundwater level is found to be 3 cm below the bed bottom, but at the same time, there was water in the bed. The alteration within the inaccuracy limits of 5 cm mainly resulting from the inequality of the bed bottom is of no importance for us; this point is also to be considered to be spring. The springs at the points 26, 28, and 30 cannot provide surface water at the sampling sites located 100 m further down along the stream. The spring at point 22 provides surface water along a section stretching at least 200 metres. Comparing the two figures it can also be stated that going downwards from point 19 to the end of the examined segment the water in the bed comes from the upper segment in each case, as there are no places where groundwater would come to the surface. Consequently, the 1.8 km long segment between the sampling point 1 and 19 can be considered uniformly influent during the examination period.

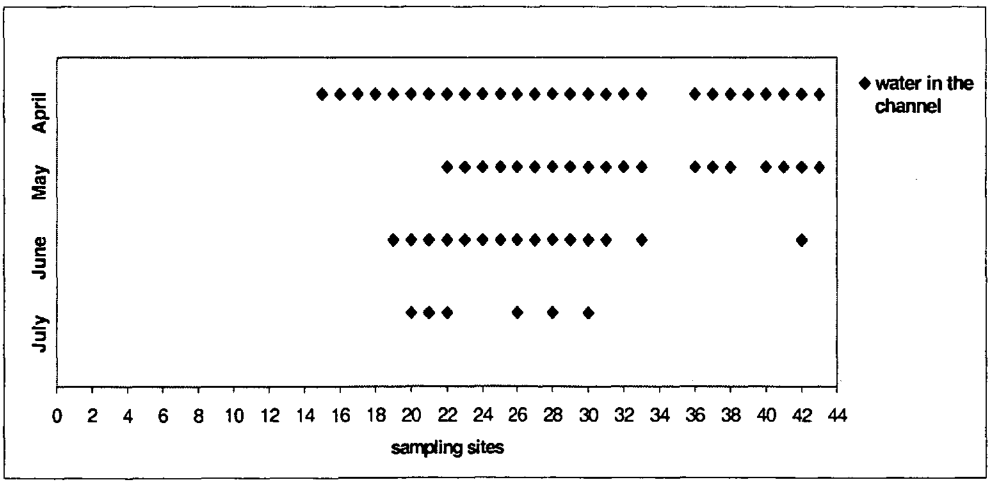


Figure 5. Surface water occurring in the stream bed at different times

The segment bordered by the sampling sites 33 and 44 is characterized by the fact that in comparison with the values from April and May, the decrease in June and July was more significant. On this segment there were only two places where there was water in the bed at the time of the recording in June, and the whole segment turned out to be completely dry at the time of the recording carried out in July.

Results of the pedological analysis

The lowest Arany-type cohesion index fell under the category sandy loam soil, while the highest index fell under the category heavy clay soil (STEFANOVITS, 1999). There is no unambiguous trend alongside the stream. The same may be said in connection with the results concerning the vegetable matter content, as well. The two parameters are in close relation with each other on the basis of the run of the curves. The proposed pedological examinations include determining the distribution of individual particles as well as the cubic mass of the undisturbed samples.

General characterization of the vegetation of the stream bed

The vegetation of the regulated bed cannot be satisfactorily described by listing the communities occurring. The fact that species having different coenological preferences and habitat needs occur "mixed", located near each other is probably the result of the small transversal dimension and of the few species available as well as of the man-made bed shape. Consequently, there are only few points where the characteristic physiognomic picture of some combinations can be observed. The types that still occur and can be unambiguously identified, outline a coenologically "idealized" picture. Based on the National Habitat Classification System (FEKETE ET AL., 1997; BÖLÖNI ET AL., 2003), which is rooted in coenology, after field studies made on several occasions the following picture can be outlined:

The vegetation on the segments where there is water in the bed during the summer for a long time (July-August) is *Glyceria, Sparganum and Schoenoplectus beds* (B2). The most typical species of this kind of vegetation are the following: *Glyceria plicata, Sium erectum, Catabrosa aquatica.* Typically, this zone is accompanied by a string of tall herb communities (*Water-fringing and fen tall herb communities* D5). Characteristic species: *Angelica sylvestris, Mentha longifolia, Epilobium hirsutum. Caricetum acutiformis-riparial* can be seen at some places (*Non-tussock beds for large sedges* B5). Typical species: *Carex acutiformis.* There are some places in the bed that are covered with sedge-marshes (*Eu- and mesotrophic reed and Typha beds* B1a). *Phragmites communis* és *Calystegia sepium* are the most common species.

These habitats often mix with each other, or with uncharacteristic treeless communities (*Uncharacteristic meadows and tall herb communities OB, Uncharacteristic wetlands OA*) forming a "network" difficult to be segmented.

Evaluation based on the coenological samples and the recordings concerning water supply

According to the mean WBs calculated from the group-proportion of the coenological examinations (**Fig. 6.**) it can be seen that there is a declining tendency from sampling point 22 to the lower end (point 1) of the segment analysed. Relying on the evidence represented by the graphs indicating the distance between the groundwater-plane and the surface (**Fig. 4.**) and showing the wet-dry points (**Fig. 5.**) it can be concluded that on this segment there are no such points where the groundwater directly supplies the stream with water except for point 22.

The water in the bed originates from the surface onflows. The declining tendency of the WB index can be explained with the fact that the surface water entering the bed leaks away, consequently, it keeps the lower section wet to a declining extent. **Figure 5.** serves also as a proof of this hypothesis. Below point 15 the bed was always found dry at the four samplings. The distribution of the WB2, WB3, WB4 categories (**Fig. 7.**) suggest a similar conclusion. Species connected to WB2 values occur only on the lowest segment of the stream (in small percentage). The percentage of the occurrence of the species connected to WB3, WB4 is increasing towards point 1, while the percentage of the occurrence of the species connected to WB7, WB8, WB9 shows a declining tendency.

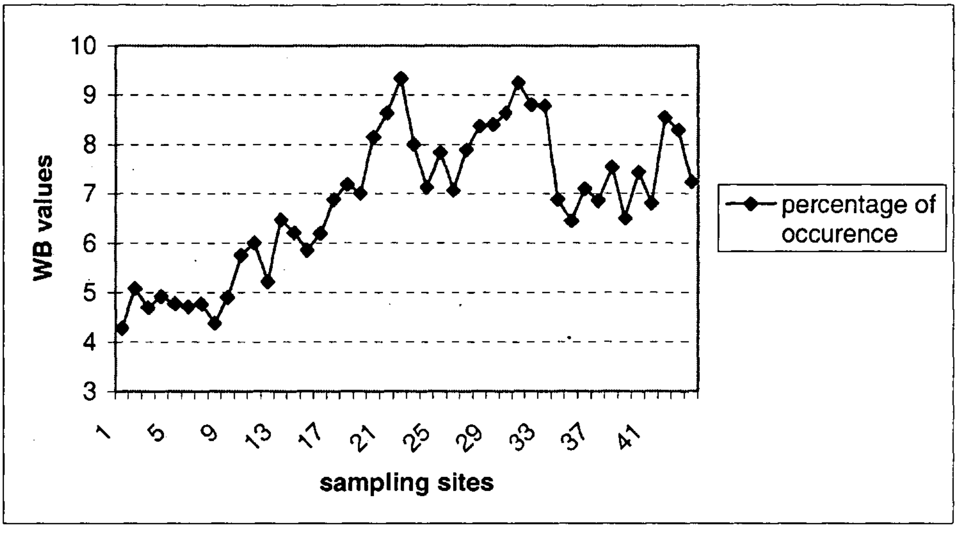
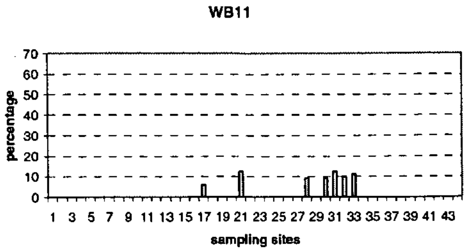
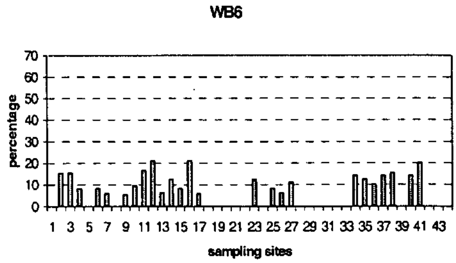
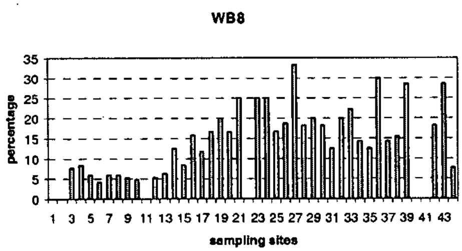


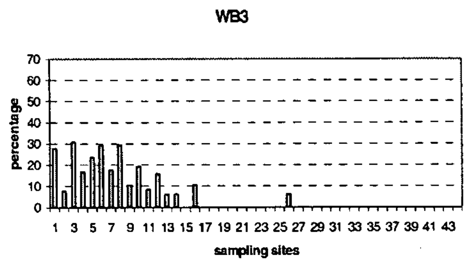
Figure 6. Mean WB calculated from the percentage of occurrence within the group of the coenological samples

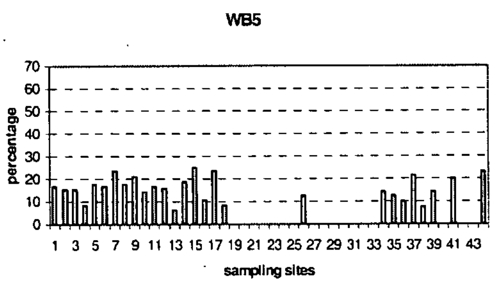
The comparison of the segment between point 20 and 23, which was identified on the basis of the data measured directly concerning water supply, with the picture obtained basing on the vegetation is not as unambiguous as the above. Relying on the data recorded in July the low mean of point 26 (7.06) among the four points considered to be springs (22, 26, 28, 30) is especially conspicuous. According to the field minutes a 40 cm long segment of the bed is cut in a depth of approx. 30 cm. The coverage by plants is on this "current line" 0%. The vegetation examined does not characterize the bed bottom but the layers located higher, that is drier levels. Examining the distribution of the WB values based on sampling sites it is remarkable that there are only few places where the species WB2, WB3, WB4, WB5, WB6 occur, and if they occur at all, they cover only a small area, but the species of the category WB7 have a great percentage of occurrence (similar to the species WB8., WB9, WB10.).

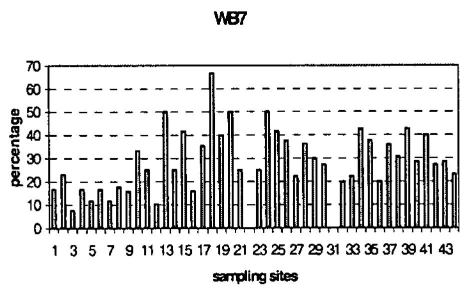

WB11
percentage
sampling sites

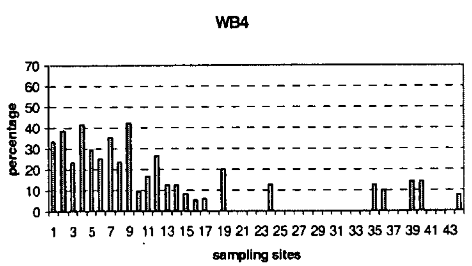

WB6
percentage
sampling sites

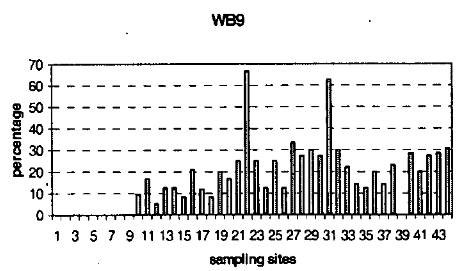

WB8
percentage
sampling sites


WB3
percentage
sampling sites


WB5
percentage
sampling sites


WB7
percentage
sampling sites


WB4
percentage
sampling sites


WB9
percentage
sampling sites

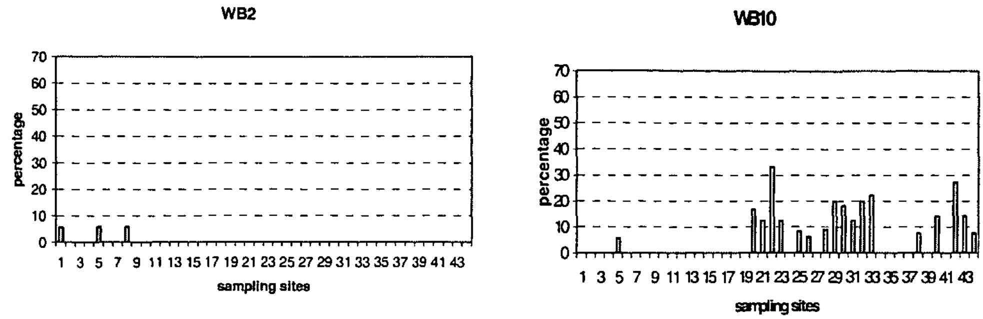


Figure 7. Proportional values calculated on the basis of the percentage of occurrence within the group per WB categories

The mean WB calculated on the segment between point 33 and 44, which was determined on the basis of the date measured concerning water supply, were recorded at the springs in June (points 42, 33). As opposed to the previous group, analysing the distribution it can be concluded that there is no such break to be seen previously as far as the presence and percentage of occurrence of the species of category WB6 and WB7 are concerned.

The depth of the groundwater-plane on the segment from point 19 to 44 (point 26 is left out as a distinct value) measured in June in centimetre is in correlation with means of the WB indexes (percentage of occurrence within the group). The correlation coefficient is 0.81. The relation between the two variables is significant (in addition to a significance of 99%).

Determination of sub-basins

The determined greater sub-basins (**Fig. 3.**) disembogue into the stream bed north of the sampling point 20. The sideward recharge probably decreases on the lower, narrower section of the basin because only a small-sized basin has remained. The data obtained from the groundwater wells have proved this hypothesis since at no sampling times on this section did the groundwater supply the stream with water.

Summary

In our work we aim at discovering the relation between the vegetation system and water supply of a temporary short water course surrounded by fields. We directly record some parameters that determine the water supply (the groundwater depth, soil qualities), while we approach the vegetation by recording coenological data. According to our current data we can conclude that the vegetation of the stream bed (which is difficult to study on the basis of the categories of the syntaxonomical system), it seems to be organized in relation to some measured parameters regarding the water supply.

There is a strong connection between the vegetation examined on the basis of the distance of the groundwater from the bed bottom and on the basis of the mean WB values (percentage of occurrence within the group) of the bed bottom.

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